Electronic Version

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Claims

[c1] 1. A method for communicating signals between a first communication device and a second communication device using radio frequency (RF) communication techniques, comprising steps of:

a. g enerating a receive filter matrix from a signal received by a plurality of antennas of the first communication device from the second communication device, the receive filter matrix comprised of a plurality of sub-matrices each being a convolution matrix derived from a receive filter sub-vector, wherein each receive filter sub-vector defines complex weights associated with a receive tapped-delay line filter for a corresponding one of the plurality of antennas of the first communication device;

b.co m puting a principal eigenvector of a product of the receive filter matrix and a Hermitian of the receive filter matrix, the principal eigenvector comprised of a plurality of sub-vectors each having a length corresponding to a number of taps of a transmit tapped-delay line filter associated with a corresponding one of the plurality of antennas of the first communication device;

c.gen erating from the plurality of sub-vectors of the principal eigenvector a plurality of transmit filter sub-

vectors that form a transmit filter vector, each transmit filter sub-vector associated with a corresponding one of the plurality of antennas of the first communication device and defining complex weights associated with the transmit tapped-delay line filter for a corresponding one of the plurality of antennas of the first communication device; and

d.app lying the transmit filter vector at the first communication device to a signal to be transmitted from the first communication device to the second communication device.

[c2] 2.The method of claim 1, wherein the step of generating the plurality of transmit filter sub-vectors comprises equating each transmit filter sub-vector to the corresponding sub-vector of the principal eigenvector.

[c3] 3.The method of claim 1, wherein the step of generating the transmit filter vector further comprises normalizing each sub-vector of the transmit filter vector so that a total power emitted is divided equally among the plurality of antennas of the first communication device.

[c4] 4.The method of claim 3, wherein the step of normalizing comprises computing the norm of each of the plurality of sub-vectors of the principal eigenvector and dividing each sub-vector of the principal eigenvector by the

norm and by the square root of the number of plurality of antennas of the first communication device.

[c5] 5.The method of claim 1, wherein steps (a) through (c) are performed each time a signal is received at the first communication device from the second communication device to update the transmit filter vector and step (d) is performed with the updated filter vector when subsequently transmitting a signal to the second communication device.

[c6] 6.A me dium encoded with instructions that, when executed, perform a method comprising the steps of:
a.gene rating a receive filter matrix from a signal received by a plurality of antennas of a first communication device from a second communication device, the receive filter matrix comprised of a plurality of submatrices each being a convolution matrix derived from a receive filter sub-vector, wherein each receive filter sub-vector defines complex weights associated with a receive tapped-delay line filter for a corresponding one of the plurality of antennas of the first communication device;
b.comp uting a principal eigenvector of a product of the receive filter matrix and a Hermitian of the receive filter matrix, the principal eigenvector comprised of a plurality of sub-vectors each having a length corresponding to a number of taps of a transmit tapped-delay line filter as-

sociated with a corresponding one of the plurality of antennas of the first communication device;

c.gene rating from the plurality of sub-vectors of the principal eigenvector a plurality of transmit filter sub-vectors that form a transmit filter vector, each transmit filter sub-vector associated with a corresponding one of the plurality of antennas of the first communication device and defining complex weights associated with the transmit tapped-delay line filter for a corresponding one of the plurality of antennas of the first communication device; and

d.appl ying the transmit filter vector at the first communication device to a signal to be transmitted from the first communication device to the second communication device.

[c7] 7.The medium of claim 6, wherein the instructions encoded on the medium for performing the step of generating the plurality of transmit filter sub-vectors comprise instructions for equating each transmit filter sub-vector to the corresponding sub-vector of the principal eigenvector.

[c8] 8.The medium of claim 6, wherein the instructions encoded on the medium for performing the step of generating the transmit filter sub-vectors further comprise instructions for normalizing each sub-vector of the trans-

mit filter vector so that a total power emitted is divided equally among the plurality of antennas of the first communication device.

[c9] 9.The medium of claim 8, wherein the instructions encoded on the medium for performing the step of normalizing comprise instructions that compute the norm of each of the plurality of sub-vectors of the principal eigenvector and divide each sub-vector of the principal eigenvector by the norm and by the square root of the number of plurality of antennas of the first communication device.

[c10] 10.The medium of claim 6, and further comprising instructions encoded on the medium that repeat steps (a) through (c) each time a signal is received at the first communication device from the second communication device to update the transmit filter vector and step (d) is performed with the updated transmit filter vector when subsequently transmitting a signal to the second communication device.

[c11] 11.The medium of claim 6, wherein the instructions associated with the computations of steps (a) through (d) are implemented by one or more arrays of gates.

[c12] 12.A ba seband signal processing integrated circuit de-

vice comprising the one or more arrays of gates of claim 11.

[c13] 13.A co mmunication device comprising the baseband signal processing integrated circuit device of claim 12, and further comprising:

a.a tr ansmitter coupled to the baseband signal processing integrated circuit and to be coupled to the plurality of antennas to upconvert transmit signals generated by the baseband signal processing integrated circuit for transmission via respective ones of the plurality of antennas; and

b.a re ceiver coupled to the baseband signal processing integrated circuit and to be coupled to the plurality of antennas to downconvert signals received by the plurality of antennas and to produce receive signals that are coupled to the baseband signal processing integrated circuit.

[c14] 14.The medium of claim 6, wherein the instructions are processor readable instructions, that when executed by a processor, cause the processor to perform steps (a) through (d).

[c15] 15.A se miconductor device comprising a plurality of gates configured to implement:

a.a pl urality of transmit tapped delay-line filters, each

associated with a corresponding one of a plurality of antennas;

b.a pl urality of receive tapped delay-line filters, each associated with a corresponding one of the plurality of antennas;

c.one o r more computation blocks that:

i.gener ate a receive filter matrix from a signal received by the plurality of antennas of a communication device from another communication device, the receive filter matrix comprised of a plurality of sub-matrices each being a convolution matrix derived from a receive filter sub-vector, wherein each receive filter sub-vector defines complex weights associated with a corresponding receive tapped-delay line filter;

ii.compu te a principal eigenvector of a product of the receive filter matrix and a Hermitian of the receive filter matrix, the principal eigenvector comprised of a plurality of sub-vectors each having a length corresponding to a number of taps of a corresponding transmit tapped-delay line filter;

iii.gener ate from the plurality of sub-vectors of the principal eigenvector a plurality of transmit filter sub-vectors that form a transmit filter vector, each transmit filter sub-vector associated with a corresponding one of the plurality of antennas of the first communication device and defining complex weights associated with a

corresponding transmit tapped-delay line filter; and
iv.apply the transmit filter vector at the communication device to a signal to be transmitted to the other communication device.

[c16] 16.The se miconductor device of claim 15, wherein the computation blocks generate the plurality of transmit sub-vectors by equating each transmit filter sub-vector to the corresponding sub-vector of the principal eigenvector.

[c17] 17.The se miconductor device of claim 15, wherein the computation blocks generate the transmit filter sub-vectors by normalizing each sub-vector of the transmit filter vector so that a total power emitted is divided equally among the plurality of antennas of the communication device.

[c18] 18.The se miconductor device of claim 17, wherein the computation blocks normalize each sub-vector of the transmit filter vector by computing the norm of each of the plurality of sub-vectors of the principal eigenvector and dividing each sub-vector of the principal eigenvector by the norm and by the square root of the number of plurality of antennas of the communication device.

[c19] 19.The se miconductor device of claim 15, wherein the

computation blocks repeat the computations of steps (i) through (iii) each time a signal is received at the communication device from the other communication device to update the transmit filter vector and step (iv) is performed with the updated transmit filter vector when subsequently transmitting a signal to the other communication device.

[c20] 20.A radi o communication device comprising the semiconductor device of claim 15, and further comprising:

a.a plur ality of antennas;

b.a tran smitter coupled to the plurality of antennas and to the semiconductor device to upconvert transmit signals generated by the semiconductor device for transmission via respective ones of the plurality of antennas; and

c.a rece iver coupled to the plurality of antennas and to the semiconductor device to downconvert signals received by the plurality of antennas and produce receive signals that are coupled to the semiconductor device.

[c21] 21.A meth od for communicating signals between a first communication device and a second communication device using radio frequency (RF) communication techniques, comprising steps of:

a.proces sing with a transmit filter vector a signal to be transmitted from the first communication device via a

plurality of antennas of the first communication device to the second communication device, the transmit filter vector comprised of a plurality of transmit filter sub-vectors defining one or more complex weights associated with a transmit tapped-delay line filter, each transmit filter sub-vector associated with a corresponding one of the plurality of antennas of the first communication device and having a length corresponding to the number taps of the associated transmit tapped-delay line filter; and

b.proces sing with a receive filter matrix a signal received from the second communication device at the plurality of antennas of the first communication, wherein the receive filter matrix comprises a plurality of sub-matrices each being a convolution matrix derived from a receive filter sub-vector, wherein each receive filter sub-vector defines complex weights associated with a receive tapped-delay line filter for a corresponding one of the plurality of antennas of the first communication device.

[c22] 22.The me thod of claim 21, wherein when a signals is received at the plurality of antennas of the first communication device from the second communication device, further comprising steps of :

a.comput ing a principal eigenvector of a product of the receive filter matrix and a Hermitian of the receive filter

matrix, the principal eigenvector comprised of a plurality of sub-vectors each having a length corresponding to the number of taps of the transmit tapped-delay line filter of the first communication device; and
b.updati ng the transmit filter sub-vectors with the plurality of sub-vectors of the principal eigenvector for use when transmitting a signal to the second communication device.

[c23] 23.The me t hod of claim 22, wherein the step of computing further comprises computing the norm of each of a plurality of sub-vectors of the principal eigenvector and dividing each sub-vector of the principal eigenvector by the norm and by the square root of the number of plurality of antennas of the first communication device so that when the transmit filter vector is applied to a signal to be transmitted, a total power emitted is divided equally among the plurality of antennas of the first communication device.

[c24] 24.A mediu m encoded with instructions that, when executed, perform a method comprising the steps of:
a.process ing with a transmit filter vector a signal to be transmitted from a first communication device via a plurality of antennas of the first communication device to a second communication device, the transmit filter vector comprised of a plurality of transmit filter sub-vectors

defining one or more complex weights associated with a transmit tapped-delay line filter, each transmit filter sub-vector associated with a corresponding one of the plurality of antennas of the first communication device and having a length corresponding to the number taps of the associated transmit tapped-delay line filter; and

b.process ing with a receive filter matrix a signal received from the second communication device at the plurality of antennas of the first communication, wherein the receive filter matrix comprises a plurality of sub-matrices each being a convolution matrix derived from a receive filter sub-vector, wherein each receive filter sub-vector defines complex weights associated with a receive tapped-delay line filter for a corresponding one of the plurality of antennas of the first communication device.

[c25] 25.The med ium of claim 24, and further comprising instructions encoded on the medium to further perform steps of:

a.computi ng a principal eigenvector of a product of the receive filter matrix and a Hermitian of the receive filter matrix when a signal is received at the plurality of antennas of the first communication device from the second communication device, the principal eigenvector comprised of a plurality of sub-vectors each having a length corresponding to the number of taps of the transmit

tapped-delay line filter of the first communication device; and

b.updatin g the transmit filter sub-vectors with the plurality of sub-vectors of the principal eigenvector for use when transmitting a signal to the second communication device.

[c26] 26.The med ium of claim 25, wherein the instructions encoded on the medium for performing the step of computing further comprise instructions for computing the norm of each of a plurality of sub-vectors of the principal eigenvector and dividing each sub-vector of the principal eigenvector by the norm and by the square root of the number of plurality of antennas of the first communication device so that when the transmit filter vector is applied to a signal to be transmitted, a total power emitted is divided equally among the plurality of antennas of the first communication device.

[c27] 27.The medi um of claim 24, wherein the instructions are implemented by one or more arrays of gates.

[c28] 28.A baseba nd signal processing integrated circuit device comprising the one or more arrays of gates or claim 27.

[c29] 29.A commun ication device comprising the baseband

signal processing device of claim 28, and further comprising:

a.a transm itter coupled to the baseband signal processing integrated circuit and to be coupled to the plurality of antennas to upconvert transmit signals generated by the baseband signal processing integrated circuit for transmission via respective ones of the plurality of antennas; and

b.a receiv er coupled to the baseband signal processing integrated circuit and to be coupled to the plurality of antennas to downconvert signals received by the plurality of antennas and to produce receive signals that are coupled to the baseband signal processing integrated circuit.

[c30] 30.The medi um of claim 24, wherein the instructions are processor readable instructions that, when executed by a processor, cause the processor to perform steps (a) and (b).

[c31] 31.A radio c ommunication device comprising:

a.N plurali ty of antennas;

b.a baseban d signal processor that generates transmit signals and that recovers data from receive signals; and

c.a radio t ransceiver coupled to the baseband signal processor that upconverts the transmit signals for transmission via the N plurality of antennas and downconverts

signals received by the N plurality of antennas to produce receive signals;

d.wherein t he baseband signal processor:

i.processes with a transmit filter vector a signal to be transmitted from via the N plurality of antennas to another communication device, the transmit filter vector comprised of a plurality of transmit filter sub-vectors defining one or more complex weights associated with a transmit tapped-delay line filter, each transmit filter sub-vector associated with a corresponding one of the N plurality of antennas and having a length corresponding to the number taps of the associated transmit tapped-delay line filter; and

ii.processes with a receive filter matrix a signal received at the N plurality of antennas from the other communication device, wherein the receive filter matrix comprises a plurality of sub-matrices each being a convolution matrix derived from a receive filter sub-vector, wherein each receive filter sub-vector defines complex weights associated with a receive tapped-delay line filter for a corresponding one of the N plurality of antennas.

[c32] 32.The radio communication device of claim 31, wherein when signals are received from the other communication device at the N plurality of antennas, the baseband signal processor computes a principal eigenvector of a

product of the from a signal received from the second communication device and a Hermitian of the receive filter matrix, the principal eigenvector comprised of a plurality of sub-vectors each having a length corresponding to the number of taps of the transmit tapped-delay line filter of the first communication device; and updates the transmit filter sub-vectors with the plurality of sub-vectors of the principal eigenvector for use when transmitting a signal to the other communication device.